A Distributed Smart PEV Charging Algorithm Based on Forecasted Mobility Energy Demand

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December 9, 2016

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Overview

Motivation and EVGI Problem

Problems with Grid integration of PEVs

- Mass penetration of PEVs will put grid under more stress.

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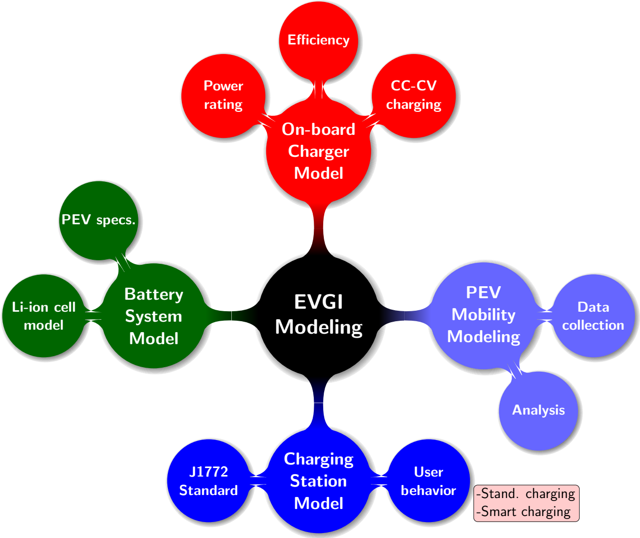
- Unidirectional (V1G) and Bidirectional (V2G) solutions are possible

Motivation and EVGI Problem

Our contribution:

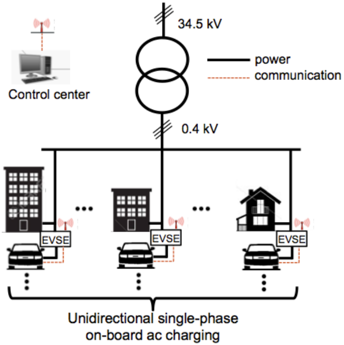
- A distributed smart charging algorithm to decrease peak loading and to fill the night valley
- Ensure full SOC in the morning
- Variable charging with min 6 A charging current per PEV as defined in SAE J1772
- Computation of a variable grid preferred operation point (POP) depeding on the charging load
- Reduced bidirectional communication flow

EVGI Modeling Components



Distribution System Setting and PEV Models

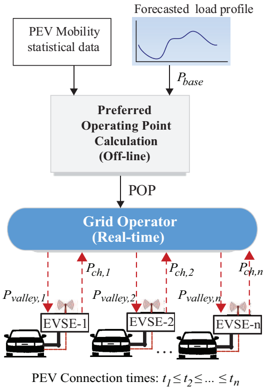
- Three-phase 1 MVA distribution grid with 980 residential customers
- Extraction of mobility distribution parameters from collected data



Types of PEVs and Their Specifications

Vehicle Make and Model	Vehicle Type	Battery Size (kWh)	EV Range (km)	Max. charge power (kW)
BMW i3	EV	18	110	7.4
Chevy Volt	PHEV	10	50	3.3
Nissan Leaf	EV	24	150	6.6
Renault Zoe	EV	22	100	7.4
Tesla Model S	EV	85	350	10

Algorithm Operation



Algorithm 1 POP estimation algorithm

1) Generate the mobility and base load data
2) Compute $E_{required}$
3) Initialize POP value to peak of base load at noon
4) Calculate E_{valley}

```
check_convergence = Inf
while |E_required − E_valley| < check_convergence do
    if E_required > E_valley then
        increment POP value
    else
        decrement POP value
    end if
    check_convergence ← |E_required − E_valley|
    update E_valley
end while
```

Algorithm Operation, cnt'd

Off-line operation:

$$E_{valley} = \int_{t_{arr,1}}^{t_{dept,ave}} P_{valley}(t)dt,$$

where,

$$P_{valley}(t)=\begin{cases} POP-P_{base}(t), & \text{if } POP-P_{base}(t)>0 \\ 0, & \text{otherwise} \end{cases}$$

Algorithm Operation, cnt'd

On-line operation:

$$E_{valley,i}(t)=\int_{t}^{t_{dept,i}} P_{valley}(\tau)d\tau, \quad t_{arr,i}<t<t_{dept,i}$$

$$\alpha_i(t)=\begin{cases} \frac{E_{rated,i}\times(1-SOC_i(t))}{E_{valley,i}(t)}, & \text{if } t_{arr,i}<t<t_{dept,i} \\ 0, & \text{otherwise} \end{cases}$$

$$P_{ch,i}(t) = \alpha_i(t) \times P_{valley}(t)$$

$$P_{ch,i}(t)=\begin{cases} 0 \text{ kW}, & \text{if } \ 0<P_{ch,i}<0.66 \text{ kW} \\ 1.32 \text{ kW} & \text{if } \ 0.66 \text{ kW}<P_{ch,i}<1.32 \text{ kW} \end{cases}$$

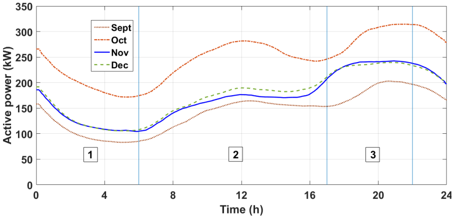
$$P_{valley}(t) = P_{valley}(t) - P_{ch,i}(t), \quad 0h < t < 24h$$

Highlights of Algorithm

- Reduced communication rate
- Low computational load
- Non-iterative, individually distributed
- Privacy kept at the charging station

Distribution Grid Features

Daily average active power demands for four months:



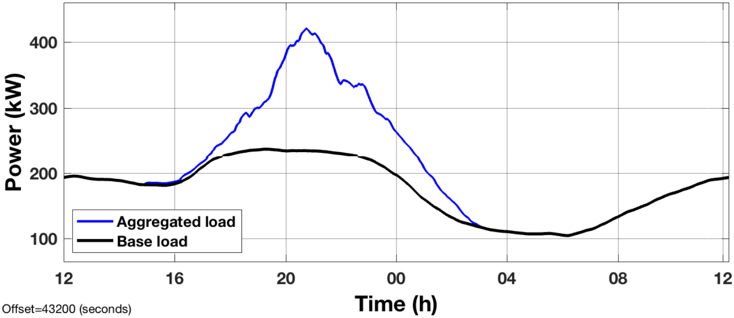
Total penetration is 10% of # of customers.

Case scenarios:

1. 100% Standard charging
2. 50% Standard charging + 50% Smart charging
3. 100% Smart Charging

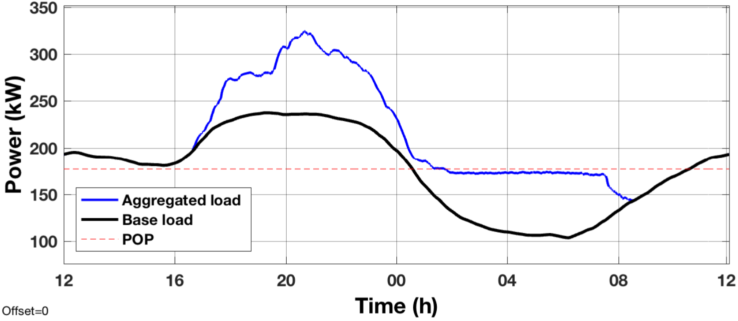
Results for the Case#1

Result of 10% PEV penetration for Case 1 (100% standard charging).



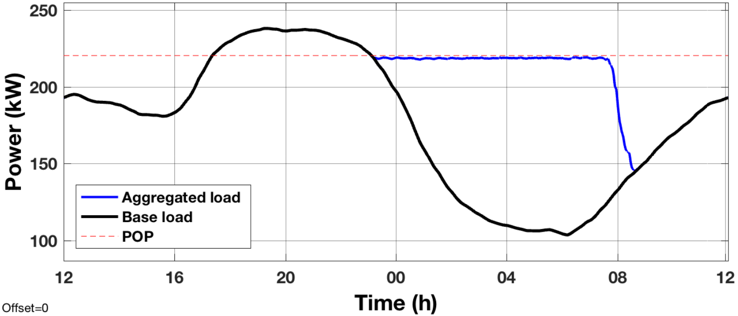
Results for the Case#2

Result of 10% PEV penetration for Case 2 (50% standard+ 50% smart charging).



Results for the Case#3

Result of 10% PEV penetration for Case 3 (100% smart charging).



Numerical Results

$$MSE = \frac{1}{t_2 - t_1} \sum_{t=t_1}^{t_2} P_{aggr}(t) - POP)^2 \quad \sigma^2 = \frac{1}{t_{dept,ave} - t_{arr,ave}} \sum_{t=t_{arr,ave}}^{t_{dept,ave}} (P_{aggr}(t) - \mu)^2$$

Case #	Standard charging PEVs [%]	Smart charging PEVs [%]	MSE* $(kW)^2$	Variance† $(kW)^2$
1	100	0	N/A	12405
2	50	50	17.4	3304
3	0	100	1.9	51.7

*Calculated between 1:00 am and 7:00 am.

†Calculated between 7:55 pm and 7:47 am next day.

Conclusions and Future Work

Conclusions

- Smart charging on distribution grid to smoothen load profile
- User convenience addressed w/ 100% charge in the morning
- Tested w/ real power distribution power consumption
- Performed better than reported algorithms (under review)

Future Work

- Provide service other than load leveling, i.e., load shifting
- Implement in lab using cyber-physical systems to verify comm. rates

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